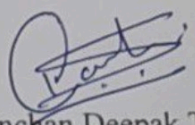
ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to all those who have supported and guided me for the course of this research work on **"SignBridge: A 2D Multimodal Framework for Indian Sign Language Recognition and Translation into Marathi Language."**

First and foremost, I extend my sincere thanks to my esteemed guide, **Dr. Sarita Ambadekar**, for her constant encouragement, expert guidance, and valuable insights at every stage of this research. Her mentorship has been invaluable in shaping the direction and depth of this work .I am also deeply grateful to **Dr. Hariram Chavan**, Ph.D. Coordinator, for his continuous support, constructive suggestions, and guidance throughout the research process. His experience and vision have played a significant role in refining the scope and methodology of this project. I would like to express my sincere appreciation to our respected **Dr. Vivek Sunnapwar, Principal**, for providing the necessary academic environment, infrastructure, and encouragement to carry out this research at **K.J. Somaiya Institute of Technology, Sion, Mumbai**.

Lastly, I am deeply thankful to my family and friends for their unwavering support, patience, and belief in me throughout the completion of this research.



Kanchan Deepak Talekar

Registration No: 2220240792

INDEX

Abstract		i
List of Figures		ii
List of Tables		iii
1	Aim of the Study	1
2	Study background (Literature review) and Significance of Study	3
3	Objectives of Study	10
4	National Status	11
5	International Status	12
6	Study Hypothesis	13
7	Study Rationale	13
8	Research Methodology	14
9	Statistical plan	17
10	Limitations of the Study	17
11	Expected Outcomes of the Study	18
12	Bibliography	18
13	Appendix	23
14	Plagiarism Report	28

ABSTRACT

The lack of communication between hearing-impaired individuals and the general public continues to be a big challenge for social inclusion and accessibility.Indian Sign Language (ISL), the primary means of communication for many deaf individuals in India, lacks sufficient technological support for automatic recognition and translation. SignBridge is a comprehensive framework developed to bridge this gap by enabling real-time ISL translation, fostering effective interaction between hearing and non-hearing individuals. The system leverages advanced Deep Learning (DL) techniques including Convolutional Neural Networks (CNNs) and Transformers for accurate gesture recognition. It also integrates Natural Language Processing (NLP) to ensure meaningful, context-aware translation between sign language and natural language.

The platform supports multiple input modes, including gestures, speech, and text, offering flexible and inclusive user engagement. A key feature of SignBridge is its ability to accommodate regional variations of ISL, enhancing its linguistic and cultural relevance across India. Beyond translation, the system offers interactive learning tools to support ISL education for non-signers, educators, and learners. By addressing both communication and educational needs, SignBridge contributes to greater awareness, accessibility, and social inclusion. Future improvements include mobile platform integration, expansion to additional regional dialects, and multilingual sign translation capabilities.

LIST OF FIGURES

Fig. No.	Figure Name	Page No
Fig 1.1	Types of Sign	1
Fig 1.2	Hand gestures for the ISL alphabets	2
Fig 1.3	Sign Language Recognition Methods	3
Fig. 8.1	Proposed Methodology	15

LIST OF TABLES

Table. No	Table Name	Page No.
Table 4.1	Comparative Analysis of Various Papers	4
Table 9.1	Statistical Plan for next three years	17

1. Aim of the Study

The aim of the SignBridge framework is to develop an inclusive and intelligent communication system that bridges the gap between hearing-impaired and hearing individuals by accurately recognizing and translating Indian Sign Language (ISL).The system aims to improve digital accessibility, strengthen social inclusion, and empower individuals who are deaf or hard of hearing by enabling two-way communication, accommodating regional sign variation (Marathi) , and offering educational resources for use in daily life, education, and workplaces.

1.1 Introduction

Sign language serves as the primary mode of communication for individuals with hearing impairments.It can convey visual information through the cooperation of multiple organs (e.g., hands, body, lips and facial expressions), and has unique characteristics different from spoken language [1]. Various types of sign languages are used around the world, such as British Sign Language, Indian Sign Language, Spanish Sign Language, American Sign Language, Chinese Sign Language, among others[2]. A sign language converter enables communication between deaf, hard-of-hearing individuals and non-signers by converting sign gestures into text or speech, and the other way around.

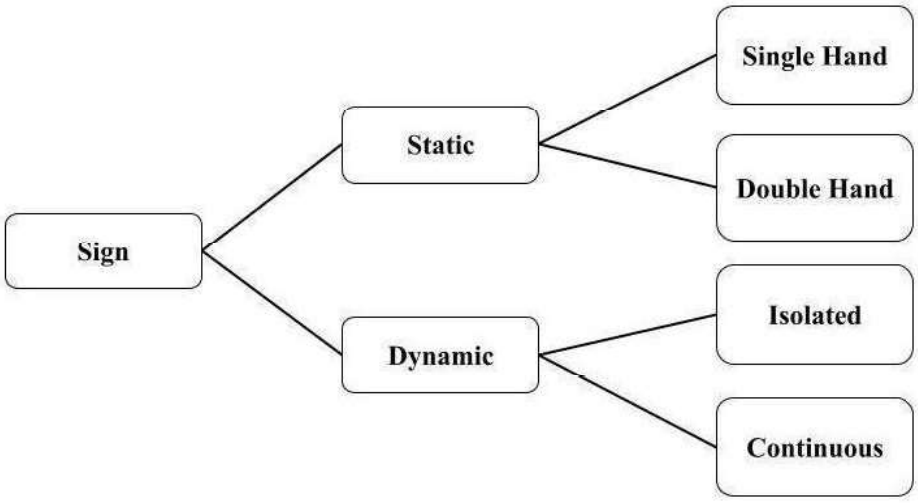


Fig 1.1 Types of Sign[2].

Figure 1.1 illustrates that sign language is broadly categorized into static and dynamic types. Static signs involve fixed hand positions using one or both hands, whereas dynamic signs are further classified into isolated gestures and continuous motion sequences.[2].

Sign language is a visual-spatial form of natural language widely used by many Deaf and Hard of Hearing (DHH) individuals as their main method of communication. According to the World Federation of the Deaf, more than 200 distinct sign languages exist globally, with approximately 70 million deaf people relying on them.[3]. For the deaf community, sign languages are integral to social, educational, and cultural interactions, fostering identity and belonging. In India, Indian Sign Language is crucial for an estimated 18 million deaf individuals. The lack of ISL awareness among officials often creates communication barriers, limiting access to healthcare, education, legal services, and government schemes. This results in the marginalization of the deaf community[4]. The ISL alphabet hand gestures are illustrated in Figure 1.2.

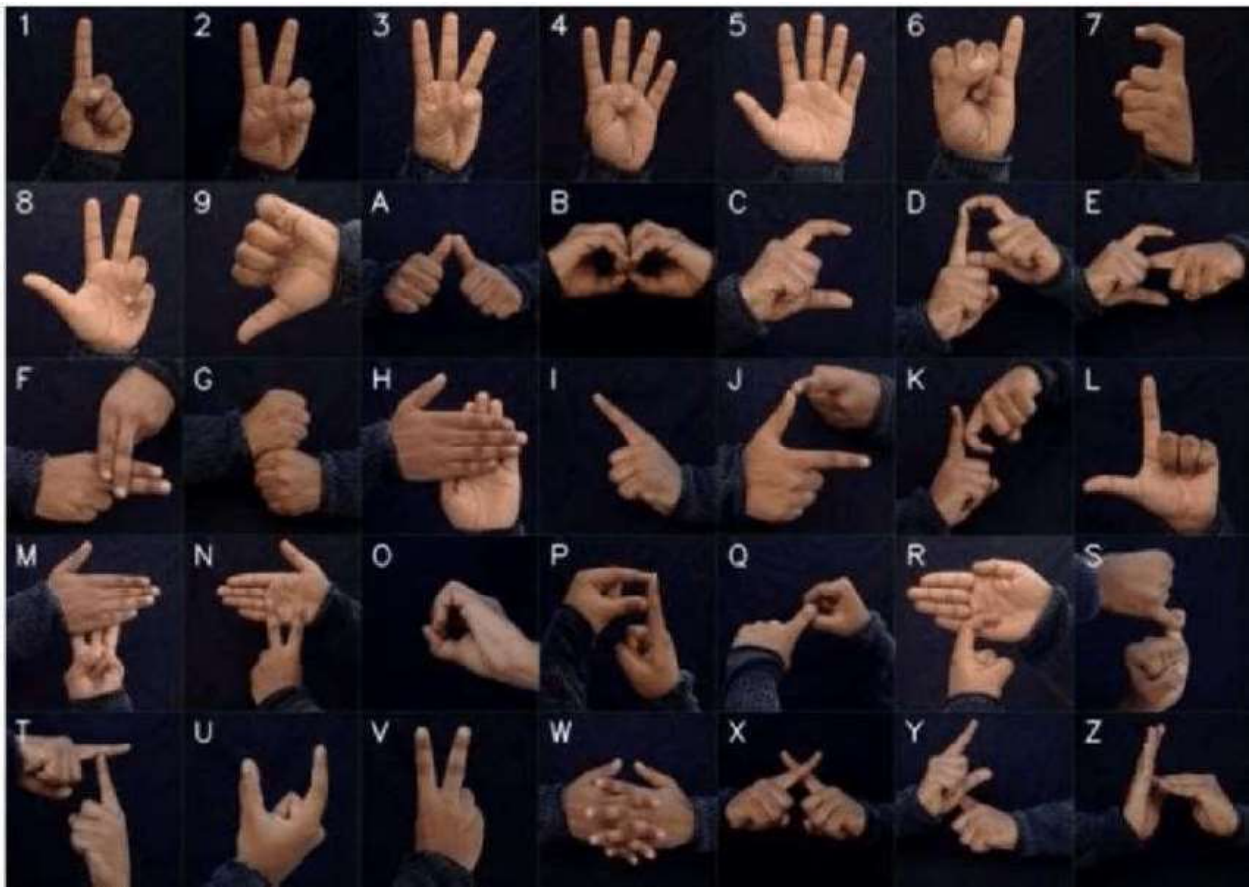


Fig 1.2 Hand gestures for the ISL alphabets

1.2 Sign Language Recognition Methods

Two primary methods used in Sign Language Recognition (SLR): glove-based and vision-based approaches are shown in Figure 1.3. In the glove-based method, users wear gloves embedded with sensors that detect hand movements and finger positions, primarily used for recognizing isolated

signs. On the other hand, the vision-based approach relies on cameras and computer vision techniques to interpret gestures without any physical devices.This approach is capable of recognizing both isolated signs and continuous sign sequences, enhancing its flexibility for real-time communication.

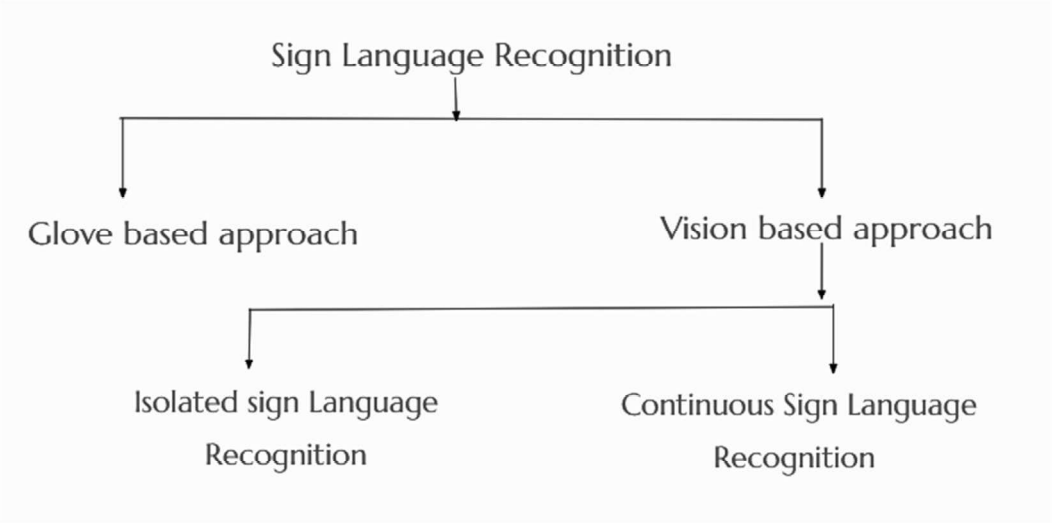


Fig 1.3. Sign Language Recognition Methods

To overcome this challenge, the proposed project presents a framework capable of recognizing and translating ISL gestures into text or speech, and vice versa, in real time. The framework also includes features for learning ISL and supports regional variation (Marathi) to ensure inclusivity and cultural relevance. Through this study, we seek to address key technological and social gaps, contributing toward a more accessible and inclusive digital communication environment in India.

2. Study background (Literature review) and Significance of Study:

2.1 Comparative Analysis of Research Papers

Table 4.1 Comparative Analysis of Research Papers

Sr. No	Authors	Title	Key Contribution	Future Scope

1	M. Geetha et al. [1]	Towards Real-Time Recognition of Continuous Indian Sign Language: A Multi-Modal Approach using RGB and Pose.	A real-time ISL recognition model was developed using video and pose information, integrating 3D-CNN with a Transformer to enhance comprehension of gestures at the sentence level.	- Increase Dataset (vocabulary) - Add Indian language variations - Use in real places (schools, hospitals, education, etc.) - Dataset not yet public - Two-way communication
2	D. R. Kothadiya et al. [2]	SIGNFORMER: DeepVision Transformer for Sign Language Recognition	Proposed SIGNFORMER , a Vision Transformer model that captures both space and time features from sign videos to improve recognition accuracy	- Lack of Dynamic Sign (Isolated/Continuous) -Support for multimodal input and output - Add more sign languages - Make it work in real-time
3	L. Chaudharyet al. [3]	SignNet II: A Transformer-Based Two-Way Sign Language Translation Model	A bidirectional sign language translation system was created using Transformer models, enabling both sign-to-text and text-to-sign conversions.	- Adaptation to Other Sign Languages -Multimodal Input Integration - Optimize for mobile and real-time translation applications.
4	Zidong Liu et al. [4]	Improving End-to-End Sign Language Translation with Adaptive Video Representation Enhanced Transformer	Introduced AVRET, which selects important visual frames and merges coarse and fine-grained features to improve sign-to-text translation accuracy	- Lack of Real-Time Evaluation - Support more languages - Improve facial expression detection - Make it work on mobile devices
5	B. Saini et al. [5]	A Comparative Analysis of Indian Sign Language Recognition Using Deep Learning Models	Conducted a comparison of CNN, LSTM, and hybrid deep learning approaches to determine the most effective technique for recognizing (ISL).	- Expand Dataset for ISL - Extend to video-based or real-time sign language - Real-Time Deployment

6	Abhinav Joshi et al. [6]	ISign: A Benchmark for Indian Sign Language Processing	Developed the first standardized dataset and defined tasks specifically for Indian Sign Language recognition and translation.	- Use iSign for training real-time translation tools, including sign generation. - Extend Vocabulary and Domains (Medical, education, Gov. Offices) -Multilingual Mapping
7	M. K. Vidhyalakshmi et al. [7]	Indian Sign Language Recognition Using Transfer Learning with EfficientNet	Applied transfer learning with EfficientNet to develop an accurate and lightweight ISL recognition system	- Extend to Dynamic Gestures - Improve real-time usage - Make it work on web/mobile platforms - Use Multimodal Data - Increase the vocabulary (word/sentence)
8	H. Ranka et al. [8]	Emotion-Aware Indian Sign Language Recognition: A Multimodal Approach With Sign-Expression Correlation Analysis	Developed a multimodal ISL recognition model that integrates emotion detection through facial expression analysis	- Use in real-time systems - Improve support for emotional and sign variations - Add regional ISL variations - Provide ISL training

J. P. Jayaraj and R. R. Kanna [9] proposed a deep learning system that detects ISL gestures and converts them into text, aiming to improve communication between hearing and hearing-impaired individuals. The model emphasizes accuracy and user-friendliness, supporting AI-based real-time assistive solutions.

F. M. Najib (2024) [10] proposed a machine learning system capable of recognizing sign languages in various languages. The model is built to interpret and translate signs across multiple linguistic settings, making it effective for use in multilingual and diverse communities. This method improves global communication access for individuals with hearing impairments.

D. Kumari and R. S. Anand (2024)[11] proposed an isolated sign language recognition system that integrates CNN and LSTM models with an attention mechanism. The CNN extracts spatial features, LSTM captures temporal patterns, and attention focuses on important gestures to improve accuracy. This approach is effective for real-time recognition of individual sign gestures.

R. Damdoo and P. Kumar (2025) [12] present a detailed survey on ISL recognition and translation techniques. The paper reviews various machine learning and deep learning approaches, highlighting their strengths, limitations, and real-world applicability. It also identifies gaps in datasets, multimodal processing, and real-time deployment. This survey serves as a foundation for researchers aiming to develop more effective ISL recognition systems.

F. M. Najib (2024) [13] developed a sign language interpretation system using machine learning and AI, designed to accurately detect hand gestures and convert them into text or speech. This solution aims to strengthen communication between the hearing-impaired and the general public. By leveraging AI, the system improves the adaptability and effectiveness of sign language recognition, highlighting the importance of intelligent technologies in creating inclusive communication tools.

H. Orovwode et al. (2024) [14] present a web-based application powered by machine learning to support sign language learning. The platform is designed to help users, especially beginners, practice and recognize sign gestures interactively. By using real-time feedback and intelligent gesture analysis, the system enhances user engagement and learning outcomes. This research highlights how AI can make sign language education more accessible and effective through online tools.

N. V. G. Kaliyaperumal and N. P. A. Gopalan (2025) [15] developed an ISL recognition system that integrates BERT for understanding language context with LSTM for processing gesture sequences. This hybrid method improves recognition accuracy by addressing both semantic and temporal aspects of sign language. The research highlights the importance of combining NLP and deep learning to create more inclusive and efficient sign-to-text translation systems.

N. P. D. Bormane (2024) [16] introduced an Indian Sign Language recognition system utilizing Support Vector Machine (SVM) to classify hand gestures based on extracted features. The model shows strong performance in identifying static ISL signs accurately, emphasizing its suitability for low-complexity and efficient recognition systems. This research supports the use of SVM for reliable and accessible ISL interpretation.

P. Yadav and co-authors (2024) [17] propose an AI-based system that converts natural speech and text into ISL to promote digital inclusion and accessibility. The system uses natural language processing and gesture generation techniques to create accurate ISL translations from spoken or written input. This approach aims to bridge communication gaps for the hearing-impaired,

especially in digital platforms. The study highlights the importance of AI in building inclusive technologies for real-world communication needs.

Seema Sabharwal and Priti Singla (2024) [18], authors provide an in-depth analysis of various methods and technologies used to convert ISL into text. The review highlights machine learning, deep learning, and computer vision techniques applied in gesture recognition and sign translation. It discusses the strengths and challenges of existing models, especially in handling dynamic signs and regional variations. The study serves as a useful guide for researchers aiming to develop accurate and real-time ISL-to-text systems for inclusive communication.

B. K. Triwijoyo et al. (2023) [19] introduced a deep learning method for sign language recognition using video input. The research investigates the use of convolutional neural networks (CNNs) and similar models to effectively detect and classify hand gestures. The approach achieves high accuracy in identifying both static and dynamic signs, contributing to the advancement of smart communication tools for the hearing-impaired.

B. M. Gunji and colleagues (2021) [20] proposed a sign language recognition system designed to interpret sign language by accurately detecting and analyzing hand gestures. The study uses image processing and machine learning techniques to detect and classify hand signs effectively. The approach focuses on improving recognition accuracy while keeping the system lightweight and practical. This research contributes to the development of assistive tools that enhance communication for the hearing-impaired.

Y. Liu et al. (2023) [21] introduced a sign language recognition technique that integrates a Feature Pyramid Network (FPN) with a Detection Transformer (DETR). This method analyzes video frames to detect hand gestures across various scales, capturing both spatial and contextual information. The approach shows strong potential for real-time and scalable sign language recognition from video input.

V. Singla, S. Bawa, and J. Singh (2024) [22] developed an improved Indian Sign Language recognition system that combines data augmentation techniques with a Visual Transformer model. Their approach enhances model performance under limited data conditions by generating diverse training samples, leading to better accuracy and generalization. The system efficiently captures

spatial patterns in hand gestures, making it suitable for real-world applications and advancing deep learning-based ISL recognition.

M. Gil-Martín and co-authors (2023) [23] propose a method for generating sign language motion based on specific sign characteristics. Their approach uses motion synthesis techniques to create realistic sign gestures by analyzing parameters like hand shape, orientation, and movement. The system aims to support automatic sign generation, which can be useful for virtual interpreters and educational tools. This research contributes to making sign language more accessible through animation and motion-based technologies.

Daniel Yang and Ethan Farah [24] proposed a real-time, continuous sign language recognition system based on Transformer architectures. Unlike models limited to isolated gestures, their approach handles uninterrupted sign sequences, enabling smoother and more natural interpretation. By leveraging Transformers, the system effectively captures contextual and long-range dependencies within video data, contributing to improved assistive communication tools for the hearing-impaired.

R. Nihalani et al. (2024) [25] introduced an Indian Sign Language recognition system utilizing a Long Short-Term Memory (LSTM) model. The system focuses on capturing the temporal flow of gesture sequences to accurately classify dynamic signs. By effectively managing time-based data, the LSTM enhances recognition performance, supporting the creation of efficient and accessible communication tools for the hearing-impaired.

N. Shahin and L. Ismail (2024) [26] conducted an in-depth survey tracing the development of sign language translation and natural language processing systems, highlighting the shift from early rule-based approaches to advanced deep learning models such as Transformers. The study presents a detailed taxonomy and compares the performance of various models used for sign language translation. It highlights the strengths and challenges of each approach, offering insights into current trends and future advancements. This work serves as a valuable resource for researchers aiming to build effective, AI-powered communication systems.

A. Ghorai and colleagues (2023) [27] developed an ISL recognition system that integrates network deconvolution with a Spatial Transformer Network (STN). This combination refines spatial details and improves feature alignment, allowing the model to effectively manage variations in hand gesture positions. The approach enhances both accuracy and adaptability, making it well-suited for practical ISL recognition tasks.

R. Rastgoo, K. Kiani, and S. Escalera (2024) [28] proposed a Transformer-based model focused on detecting boundaries within continuous sign language video streams. The system identifies where individual signs begin and end, enabling precise segmentation and translation of gesture sequences. Utilizing the attention mechanism of Transformers, the model enhances accuracy in recognizing sign transitions, contributing to more effective and natural continuous sign language recognition systems.

B. Joksimoski et al. (2022) [29] present a scoping review of technological advancements in sign language recognition. The study explores current research trends, key challenges, and future opportunities in the field, covering both hardware and software-based solutions. It highlights the need for improved datasets, real-time systems, and inclusive designs. This review serves as a valuable guide for researchers aiming to develop more effective and accessible sign language technologies.

M. Alaghband, H. R. Maghroor, and I. Garibay (2023) [30] presented a detailed survey on sign language research, emphasizing the application of machine learning methods in recognition and translation tasks. The review categorizes existing methods, datasets, and evaluation strategies while highlighting challenges like signer variability, lack of standardized data, and real-time performance. The study also identifies research gaps and emerging trends, offering guidance for future work in sign language processing using AI.

B. Saini and co-authors (2023) [31] carried out a comparative analysis of different deep learning models to evaluate their effectiveness in recognizing ISL.The research evaluates models such as CNNs, RNNs, and hybrid approaches based on their performance in identifying ISL gestures. The study helps determine which architectures are more effective and accurate for sign recognition tasks. This work supports the advancement of AI-driven ISL systems for improved communication and accessibility

C. Grover et al. (2023) [32] presents a computer vision-based system for recognizing sign language gestures in Hindi. It utilizes image processing and machine learning techniques to accurately identify hand movements. The system is designed to improve real-time communication for Hindi-speaking deaf users. The study highlights the model's effectiveness in enhancing accessibility through regional language support.

Pawan Kumar and Savita Khatri [33] worked on converting English and Hindi text into Indian Sign Language text, aiming to reduce communication barriers for the deaf community by

producing accurate ISL translations. The system leverages linguistic rules and mapping techniques to ensure meaningful translation. This work contributes to making digital content more accessible to ISLusers.

A. Shinde and R. Kagalkar [34] presented a system for recognizing Marathi Sign Language using computer vision techniques. It focuses on enhancing gesture recognition accuracy through image processing and feature extraction methods. The system interprets hand gestures to convert them into readable text. This research supports regional language inclusivity for the hearing-impaired community.

S. Rajesh Bhagwat, et al. (2024) [35] presents a machine translation system that converts Marathi text into Indian Sign Language (ISL). The study addresses the lack of accessible communication tools for the deaf community in regional Indian languages. It proposes a rule-based and animation-driven approach for converting input Marathi sentences into ISL grammar structure, followed by animated sign output.

2.1 Significance of Study

This study plays a crucial role in tackling the persistent communication barriers experienced by the deaf and mute community in India. The proposed SignBridge framework facilitates real-time, two-way interaction between Indian Sign Language (ISL) users and individuals unfamiliar with sign language. In contrast to many existing systems that mainly translate signs into text or speech, SignBridge enables mutual communication, promoting more natural and comprehensive conversations.

Furthermore, SignBridge offers learning support features, making it useful not just for communication, but also for teaching and spreading awareness about ISL. This can have a meaningful impact in education, employment, healthcare, and social settings by promoting accessibility and inclusion.

3. Objectives of Study

The objective of this research:

1. **To analyze, collect, and build a comprehensive dataset of Indian Sign Language (ISL)**

gestures for English and Marathi languages.

The dataset will include both static and continuous signs, covering words, glosses, and sentence structures in English and Marathi. Since ISL datasets especially with regional language support like Marathi are limited, this objective aims to create a custom, annotated dataset. This involves collecting gesture videos or images from native ISL users, labeling them accurately, and aligning them with both English and Marathi translations.

2. **To develop a real-time multimodal ISL recognition and translation system.**

   This objective focuses on building a responsive system that can process and translate ISL in real time. It emphasizes the integration of multiple input modes, including visual (gesture), RGB video, audio (speech), and textual data, to make the system versatile and user-friendly.

3. **To enable two-way communication between signers and non-signers.**

   This objective focuses on bridging the communication gap between signers and non-signers by enabling two-way translation. The system will convert ISL gestures into text or speech and also generate ISL animations from spoken or written language, supporting inclusive interaction in daily life.

4. **To design interactive learning tools for non-signers.**

   Beyond communication, this objective focuses on education and inclusivity. By integrating learning modules such as gesture animations, tutorials, or quizzes the system can help teachers, students, family members, or professionals who want to learn ISL. These tools can raise awareness and bridge social gaps by enabling more people to interact effectively with the deaf community.

4. National Status

Indian Sign Language (ISL) has gained growing recognition in India as a vital communication tool for the deaf and hard-of-hearing population. A significant step in this direction was the establishment of the Indian Sign Language Research and Training Centre (ISLRTC) in 2015, which focuses on promoting and standardizing ISL nationwide. The center has created official ISL dictionaries, instructional videos, and training programs for educators to enhance learning among hearing-impaired individuals [12]. Additionally, government efforts are

increasingly integrating ISL into digital platforms, educational content, and public services to foster greater inclusivity.

Despite these advancements, the national development of ISL still faces several challenges. There is a shortage of trained ISL interpreters, limited awareness in mainstream society, and a lack of integration of ISL into school curricula and public services on a wide scale. Technological innovations like ISL recognition and translation systems are still in early stages, with few scalable and real-time applications available. To bridge the communication gap effectively, more investment is needed in research, regional dialect mapping, mobile applications, and inclusive policies that support the widespread adoption of ISL across all sectors of society.

5. International Status

Internationally, Indian Sign Language has started gaining recognition as part of the broader global movement toward inclusive communication for the deaf community. According to the World Federation of the Deaf (WFD), approximately 70 million people around the world use sign language. However, due to audism, individuals who are hard of hearing (HoH) are frequently overlooked and forced to rely on alternative communication methods [12]. International bodies like the WFD and the United Nations have stressed the need to protect and promote sign language including Indian Sign Language (ISL) as part of upholding linguistic and cultural rights.India's participation in international forums has helped showcase ISL and highlighted the need for resources, standardization, and support. While global research on sign language processing is growing rapidly, ISL remains relatively underrepresented in international datasets, academic collaborations, and technology development efforts.

While countries like the United States and the United Kingdom have made notable advancements in sign language technologies particularly for American Sign Language (ASL) and British Sign Language (BSL), Indian Sign Language (ISL) still lags behind in terms of global technological integration. There remains a shortage of accessible tools and models specifically trained on ISL for international use. This presents both a challenge and an opportunity for researchers and developers to support ISL's progress by creating multilingual systems, cross-lingual translation models, and open-source datasets. Strengthening international partnerships can

significantly boost the development of ISL technologies and enhance its role in global accessibility efforts.

6. Study Hypothesis

The aim of this research is to assess how effective the SignBridge framework is in enhancing the recognition and translation of Indian Sign Language. The hypothesis for the study is stated as follows:

Null Hypothesis (H_0):

The proposed SignBridge framework does not demonstrate a statistically significant improvement over existing Indian Sign Language (ISL) recognition and translation systems in terms of accuracy, efficiency, or user accessibility. However, it still contributes to the body of knowledge by exploring multimodal input integration and regional language support in ISL processing.

Alternative Hypothesis (H_1):

The SignBridge framework significantly enhances the performance of Indian Sign Language recognition and translation by incorporating multimodal inputs (gesture, speech, text), regional language adaptability (e.g., Marathi), and learning tools, thereby improving communication between hearing and non-hearing individuals.

This hypothesis will be tested by evaluating the performance of SignBridge against traditional and existing ISL recognition systems, using both quantitative metrics such as accuracy and qualitative user feedback.

7. Study Rationale

There is a pressing need for inclusive and accessible communication solutions for the deaf and hard-of-hearing community in India. Although Indian Sign Language (ISL) serves as the main communication method for many, a considerable gap exists between ISL users and the hearing population due to limited awareness and support. The SignBridge framework aims to bridge this divide by utilizing advanced technologies to facilitate real-time translation between ISL and spoken or written language. This system is intended to enhance communication for ISL users

across various everyday environments, including education, healthcare, workplaces, and public services.

Although significant progress has been made worldwide in the field of sign language recognition, India still lacks scalable and robust ISL-based solutions that are culturally and linguistically adapted. Existing systems often overlook regional sign variations and struggle with real-time translation, making them impractical for daily use. The SignBridge initiative is motivated by the need to bridge these gaps through a comprehensive, user-friendly, and intelligent framework that supports the development of accessible digital tools. By combining artificial intelligence, computer vision, and linguistics, SignBridge aims to promote social inclusion, improve accessibility, and support equal participation for the deaf community in all aspects of life.

8. Research Methodology

The SignBridge system is structured to process and translate Indian Sign Language using a multimodal deep learning approach. The methodology consists of multiple stages, each depicted as a block within the system architecture, to facilitate smooth and accurate two-way communication between ISL users and non-signers. Figure 8.1 illustrates a well-organized representation of the key components that make up the Sign Language Processing system.

Figure 8.1 illustrates a well-organized representation of the key components that make up the Sign Language Processing system.

Input Layer

The input layer receives data from three main sources: gestures, speech, and text. Gestural input is obtained through cameras that track hand and body movements in real time. Speech is captured via microphones and then transformed into text using speech recognition technologies. Text input allows users to manually type or send textual messages. This multimodal input design ensures that both hearing-impaired and non-signing users can interact effectively with the system.

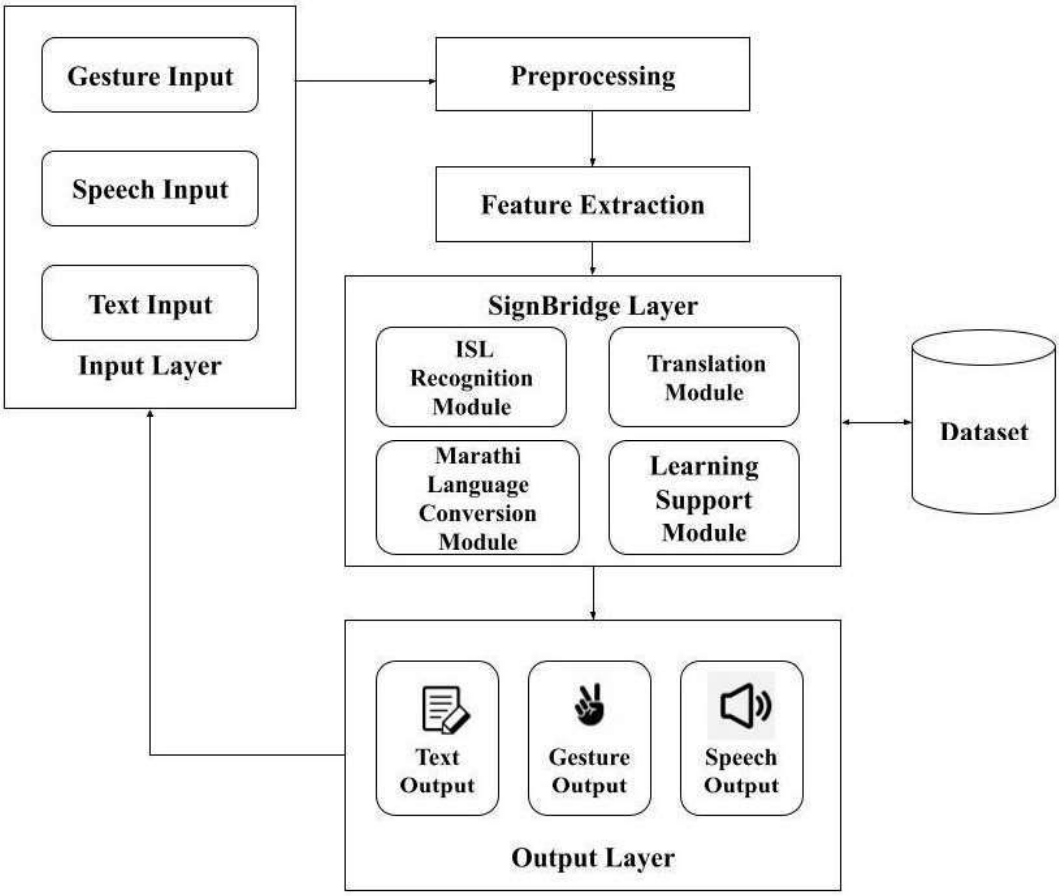


Fig 8.1 Proposed Methodology

Preprocessing

This block cleans and prepares the raw input data for further analysis. For gesture input, it may involve background subtraction, contrast adjustment, or image smoothing. For speech input, it could mean noise reduction or voice activity detection and text inputs are cleaned and tokenized. This ensures that only useful data is sent to the next stage.

Feature Extraction

In this stage, the system identifies key features from the preprocessed input. For gestures, this includes hand shape, motion direction, and joint positions. For speech, it may extract characteristics like pitch, energy, and phoneme, while text is converted into word embeddings using NLP techniques.

SignBridge Layer (Processing Core)

This is the core layer of the system where actual processing and translation take place. It includes the following modules:

1. ISL Recognition Module: Recognizes signs from the extracted gesture features using deep learning models such as CNNs or RNNs.

2. Translation Module: Converts the recognized ISL into corresponding spoken or written language (and vice versa). It also aligns text/speech inputs to ISL gestures.

3. Marathi Language Conversion Module: Specifically handles translation to and from Marathi, catering to regional language users and bridging a critical gap in localized ISL translation.

4. Learning Support Module: Provides interactive tools, tutorials, and visual aids to help non-signers, students, and educators learn ISL effectively.

Output Layer

The Output Layer is responsible for delivering the final translated message in the format best suited for the recipient, based on the original input type. It works by generating an output that complements the input mode to ensure effective communication.

1. If the input is a Gesture (sign language): The system translates the signs into Text or Speech output. This allows hearing individuals who may not understand ISL gestures to receive the message in a readable or audible form.

2. If the input is Text: The system converts the typed message into Gesture output (signs shown via an avatar or animation) or into Speech output using text-to-speech synthesis. This helps deaf or mute users receive the message in their preferred mode.

3. If the input is Speech: The system processes the spoken message and produces the output as Text or Gesture. This enables deaf users to either read the spoken message or see it expressed in sign language through an avatar.

9. Statistical plan

Sr. No.	Task	Year 1 (2024-25)	Year 2 (2025-26)	Year 3 (2026-27)
1	Literature Review & Research Design	Months 1-6		
2	Data Collection & First Paper	Months 7-12	Months 13-16	
3	Data Analysis & Second Paper		Months 17-22	
4	Third Paper & Thesis Writing		Months 23-28	Months 29-36

Table 9.1. Statistical Plan for next three years

10. Limitations of the Study

- Limited Dataset Availability: One of the primary limitations is the scarcity of large-scale, annotated ISL datasets, especially for continuous signing and regional variations. This restricts the diversity and generalizability of the trained models.
- Regional Variation Complexity: Although the system attempts to support regional ISL differences, accurately capturing and modeling all dialects across India remains a challenge due to inconsistent usage and lack of standardized data.
- Real-time Processing Constraints: Achieving consistent real-time performance with high accuracy requires substantial computational resources. Latency issues may arise on low-end or mobile devices.
- Two-way Communication Accuracy: While the framework supports bidirectional translation (text to ISL and vice versa), converting text back to sign language—especially in natural and expressive visual formats remains less accurate and is still evolving.
- Gesture Ambiguity and Occlusion: In real-world scenarios, gesture recognition may be affected by background noise, lighting conditions, or occluded hand movements, leading to recognition errors.

11. Expected Outcomes of the Study

- Real-Time ISL Recognition: Development of a system capable of accurately recognizing Indian Sign Language gestures in real time, including both isolated and continuous signs.
- Two-Way Communication Support: Implementation of a bi-directional translation system that converts ISL to text/speech and vice versa, enabling effective interaction between hearing and hearing-impaired users.
- Regional Language Support (Marathi):Integration of Marathi-specific variations in Indian Sign Language (ISL), enabling users from Maharashtra and nearby regions to communicate using their native sign dialect and preferred language.
- Multimodal Input Integration: A robust framework that accepts input through gestures, speech, or text, offering flexibility in how users interact with the system. Educational Tools for ISL Learning: Provision of built-in learning support, including animated signs and tutorials, to help users (especially non-signers) learn and understand ISL.
- Improved Social Inclusion: Enhanced communication accessibility in public services, education, workplaces, and healthcare by reducing language barriers for the deaf and hard-of-hearing community.
- Scalable and User-Friendly Interface: A prototype system with a user-friendly interface that can be extended for deployment on web or mobile platforms.

12. Bibliography

[1] M. Geetha, N. Aloysius, D. A. Somasundaran, A. Raghunath, and P. Nedungadi, "Towards Real-Time Recognition of Continuous Indian Sign Language: A Multi-Modal Approach using RGB and Pose," *IEEE Access*, p. 1, Jan. 2025, doi: 10.1109/access.2025.3554618.

[2] D. R. Kothadiya, C. M. Bhatt, T. Saba, A. Rehman, and S. A. Bahaj, "SIGNFORMER: DeepVision Transformer for Sign Language recognition," *IEEE Access*, vol. 11, pp. 4730–4739, Jan. 2023, doi: 10.1109/access.2022.3231130.

[3] L. Chaudhary, T. Ananthanarayana, E. Hoq, and I. Nwogu, "SignNet II: a Transformer-Based Two-Way sign language translation model," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, pp. 1–14, Jan. 2022, doi: 10.1109/tpami.2022.3232389.

[4] Zidong Liu, Jiasong Wu, Zeyu Shen, Xin Chen, Qianyu Wu, Zhiguo Gui, Lotfi Senhadji, and Huazhong Shu, "Improving End-to-end Sign Language Translation with Adaptive Video Representation Enhanced Transformer," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 34, no. 9, pp. 8327–8342, Mar. 2024, doi: 10.1109/tcsvt.2024.3376404.

[5] B. Saini, D. Venkatesh, N. Chaudhari, T. Shelake, S. Gite, and B. Pradhan, "A comparative analysis of Indian sign language recognition using deep learning models," *Forum for Linguistic Studies-Scopus*, vol. 5, no. 1, p. 197, Jul. 2023, doi: 10.18063/fls.v5i1.1617.

[6] Abhinav Joshi, Romit Mohanty, Mounika Kanakanti, Andesha Mangla, Sudeep Choudhary, Monali Barbate, Ashutosh Modi, "ISign: a benchmark for Indian sign language processing," *Findings of the Association for Computational Linguistics: ACL 2022, Scopus* , pp. 10827–10844, Jan. 2024, doi: 10.18653/v1/2024.findings-acl.643.

[7] M. K. Vidhyalakshmi, K. Jagadeesh, B. S. Dharmaraj, P. S. N, and R. G. Kumar, "Indian Sign Language Recognition using transfer learning with Efficient Net," *Smart Science, Scopus* , vol. 12, no. 2, pp. 269–280, Mar. 2024, doi: 10.1080/23080477.2024.2320956.

[8] H. Ranka, D. Sarda, H. Kunder, A. Rajesh, and A. Kore, "Emotion-Aware Indian Sign Language Recognition: A Multimodal Approach With Sign-Expression Correlation Analysis," *Educational Administration: Theory and Practice, Scopus*, Jun. 2024, doi: 10.53555/kuey.v30i6.7043.

[9] J. P. Jayaraj and R. R. Kanna, "Indian sign language detection and translation using deep learning," *Journal of Artificial Intelligence and Computational Technology*, vol. 1–2, no. 2, pp. 18–31, Jan. 2025, doi: 10.70593/978-81-983916-5-0_2.

[10] F. M. Najib, "A multi-lingual sign language recognition system using machine learning," *Multimedia Tools and Applications*, Sep. 2024, doi: 10.1007/s11042-024-20165-3.

[11] D. Kumari and R. S. Anand, "Isolated Video-Based Sign Language Recognition using a hybrid CNN-LSTM framework based on attention mechanism," *Electronics*, vol. 13, no. 7, p. 1229, Mar. 2024, doi: 10.3390/electronics13071229.

[12] R. Damdoo and P. Kumar, “An integrative survey on Indian sign language recognition and translation,” *IET Image Processing, Scopus*, vol. 19, no. 1, Jan. 2025, doi: 10.1049/ipr2.70000.

[13] F. M. Najib, “Sign language interpretation using machine learning and artificial intelligence,” *Neural Computing and Applications, Springer*, Nov. 2024, doi: 10.1007/s00521-024-10395-9.

[14] H. Orovwode, O. Ibukun, and J. A. Abubakar, “A machine learning-driven web application for sign language learning,” *Frontiers in Artificial Intelligence*, vol. 7, Jun. 2024, doi: 10.3389/frai.2024.1297347.

[15] N. V. G. Kaliyaperumal and N. P. A. Gopalan, “Machine learning approach for Indian Sign language recognition utilizing BERT and LSTM models,” *International Journal of Computational and Experimental Science and Engineering*, vol. 11, no. 1, Mar. 2025, doi: 10.22399/ijcesen.1276.

[16] N. P. D. Bormane, “Indian Sign Language Recognition: Support Vector Machine Approach,” *Deleted Journal*, vol. 27, no. 3, pp. 716–727, Aug. 2024, doi: 10.52783/anvi.v27.1438.

[17] P. Yadav, P. Sharma, P. Khanna, M. Chawla, R. Jain, and L. Noor, “Harnessing AI to Generate Indian Sign Language from Natural Speech and Text for Digital Inclusion and Accessibility,” *International Journal of Advanced Computer Science and Applications*, vol. 15, no. 4, Jan. 2024, doi: 10.14569/ijacsa.2024.01504114.

[18] Seema Sabharwal and Priti Singla, “Translation of Indian Sign Language to Text-A Comprehensive Review,” *International Journal of INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING, Elsevier, Scopus-Indexed*, vol. 12, no. 14, Feb. 2024.

[19] B. K. Triwijoyo, L. Y. R. Karnaen, and A. Adil, “Deep learning approach for sign language recognition,” *Jurnal Ilmiah Teknik Elektro Komputer Dan Informatika*, vol. 9, no. 1, pp. 12–21, Jan. 2023, doi: 10.26555/jiteki.v9i1.25051.

[20] B. M. Gunji, N. M. Bhargav, A. Dey, I. K. Z. Mohammed, and S. Sathyajith, “Recognition of sign language based on hand gestures,” *Journal of Advances in Applied & Computational Mathematics*, vol. 8, pp. 21–32, Dec. 2021, doi: 10.15377/2409-5761.2021.08.3.

[21] Y. Liu, P. Nand, M. A. Hossain, M. Nguyen, and W. Q. Yan, “Sign language recognition from digital videos using feature pyramid network with detection transformer,” *Multimedia Tools and Applications*, vol. 82, no. 14, pp. 21673–21685, Feb. 2023, doi: 10.1007/s11042-023-14646-0.

[22] V. Singla, S. Bawa, and J. Singh, “Enhancing Indian sign language recognition through data augmentation and visual transformer,” *Neural Computing and Applications*, vol. 36, no. 24, pp. 15103–15116, May 2024, doi: 10.1007/s00521-024-09845-1.

[23] M. Gil-Martín, M. Villa-Monedero, A. Pomirski, D. Sáez-Trigueros, and R. San-Segundo, “Sign Language Motion Generation from Sign Characteristics,” *Sensors*, vol. 23, no. 23, p. 9365, Nov. 2023, doi: 10.3390/s23239365.

[24] Daniel Yang and Ethan Farah, “Live non-isolated sign language recognition using transformers,” *Stanford School of Engineering, Stanford University.Scopus-Indexed*.

[25] R. Nihalani *et al.*, “Long Short-Term Memory (LSTM) model for Indian sign language recognition,” *Journal of Intelligent & Fuzzy Systems*, vol. 46, no. 4, pp. 11185–11203, Apr. 2024, doi: 10.3233/jifs-233250.

[26] N. Shahin and L. Ismail, “From rule-based models to deep learning transformers architectures for natural language processing and sign language translation systems: survey, taxonomy and performance evaluation,” *Artificial Intelligence Review*, vol. 57, no. 10, Aug. 2024, doi: 10.1007/s10462-024-10895-z.

[27] A. Ghorai, U. Nandi, C. Changdar, T. Si, M. M. Singh, and J. K. Mondal, “Indian sign language recognition system using network deconvolution and spatial transformer network,” *Neural Computing and Applications*, vol. 35, no. 28, pp. 20889–20907, Jul. 2023, doi: 10.1007/s00521-023-08860-y.

[28] R. Rastgoo, K. Kiani, and S. Escalera, “A transformer model for boundary detection in continuous sign language,” *Multimedia Tools and Applications-Springer Nature Link*, Apr. 2024, doi: 10.1007/s11042-024-19079-x.

[29] B. Joksimoski *et al.*, “Technological Solutions for Sign Language Recognition: A scoping review of research trends, challenges, and opportunities,” *IEEE Access*, vol. 10, pp. 40979–40998, Jan. 2022, doi: 10.1109/access.2022.3161440.

[30] M. Alaghband, H. R. Maghroor, and I. Garibay, “A survey on sign language literature,” *Machine Learning with Applications*, vol. 14, p. 100504, Oct. 2023, doi: 10.1016/j.mlwa.2023.100504.

[31] B. Saini, D. Venkatesh, N. Chaudhari, T. Shelake, S. Gite, and B. Pradhan, “A comparative analysis of Indian sign language recognition using deep learning models,” *Forum for Linguistic Studies*, vol. 5, no. 1, p. 197, Jul. 2023, doi: 10.18063/fls.v5i1.1617.

[32] C. Grover, A. Rajpoot, A. Verma, and A. Patel, “Sign Language Recognition in the Hindi Language Based on Computer Vision,” *ResearchGate*, May 2023, doi: 10.36227/techrxiv.23017775.v1.

[33] Pawan Kumar and Savita Khatri, “Generating Indian Sign Language Text Using English/Hindi Text,” *International Journal of Recent Research Aspects*, Art. no. 2349–7688.

[34] A. Shinde and R. Kagalkar, “Advanced Marathi Sign Language Recognition using Computer Vision,” *International Journal of Computer Applications*, vol. 118, no. 13, pp. 1–7, May 2015, doi: 10.5120/20802-3485.

[35] S. Rajesh. Bhagwat, R. P. Bhavsar, and B. V. Pawar, “Marathi to Indian Sign Language Machine Translation,” ACM Transactions on Asian and Low-Resource Language Information Processing, May 2024, doi: 10.1145/3664609.

13. Appendix

Survey Report Summary:

Exploring the Need for an Indian Sign Language (ISLConversion Application

A survey was conducted through Google Forms to understand the awareness, needs, and expectations surrounding an Indian Sign Language (ISL) gesture recognition and translation application. The objective was to gather insights from the general public, educators, caregivers, and stakeholders involved with the hearing-impaired community.

Purpose

The main purpose of this survey was to evaluate the demand for a sign language conversion tool and to gather ideas on how such a system could be useful in daily life for both ISL users and non-signers.

Participants:

Total responses: 59

The survey collected responses from individuals of different age groups, mainly 18–24 and 35–54. Most participants were members of the general public and caregivers, with a few educators and social workers also contributing.

Key Findings

- Over 90% of participants believe an ISL conversion app is needed.

- The biggest communication challenges for ISL users are in:

    • Schools and colleges

    • Hospitals and government offices

    • Everyday social interactions

- The most wanted features in the app include:

  • Real-time gesture recognition

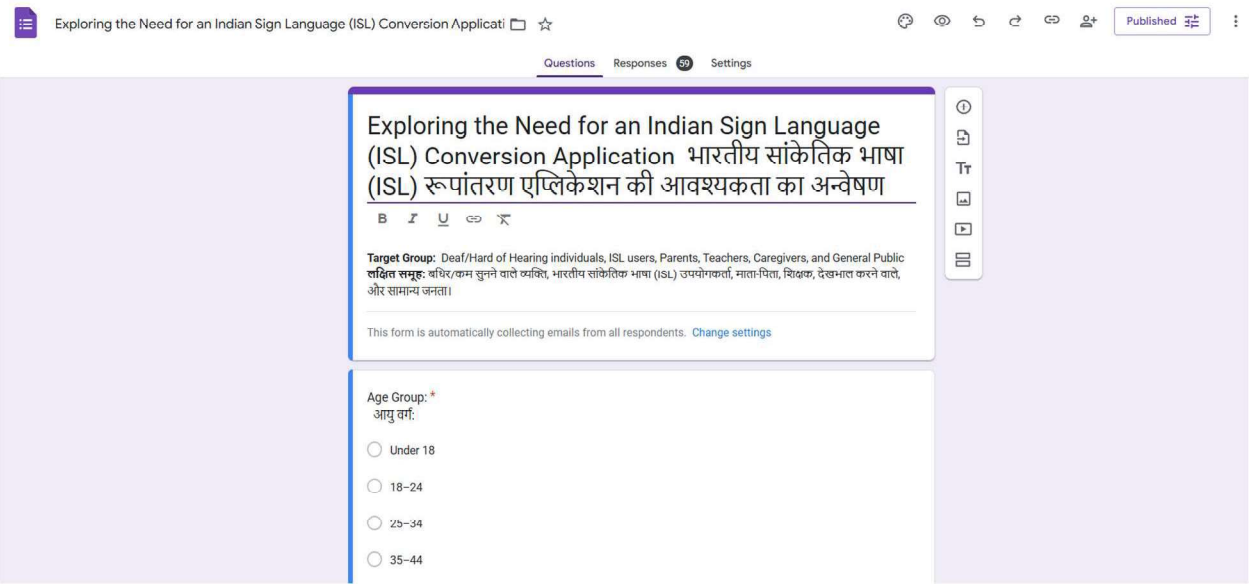
  • Text and speech output

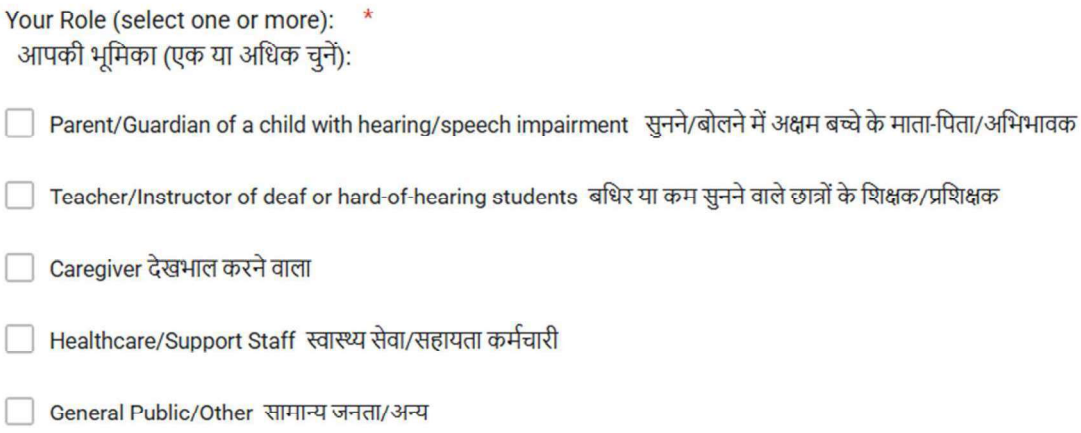
  • Multilingual and regional ISL support

• User-friendly design

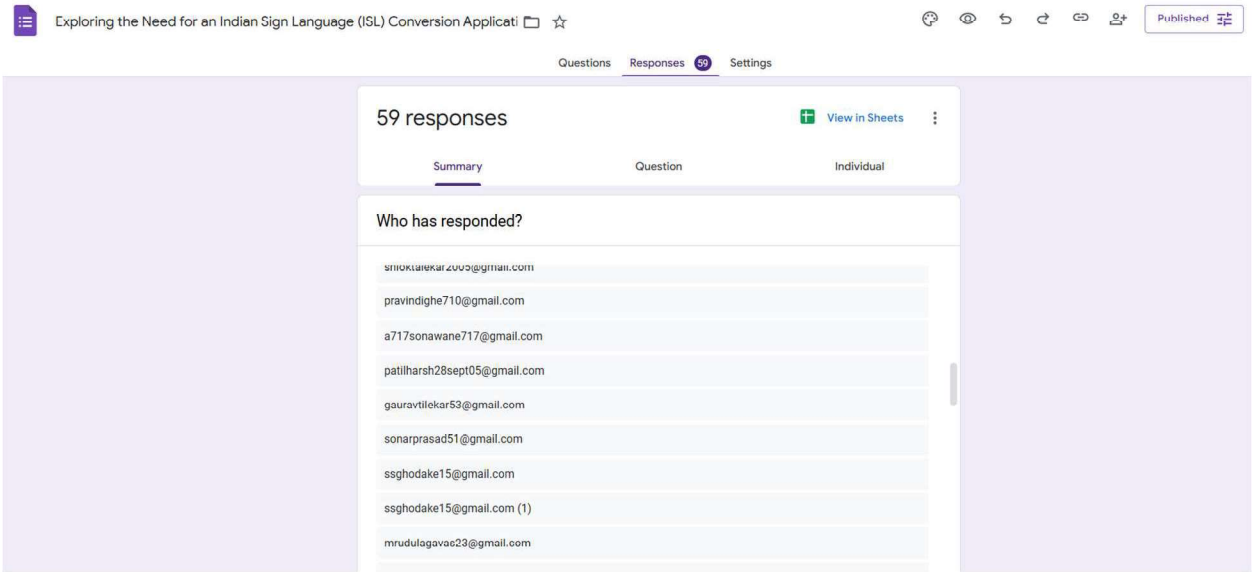
Conclusion

The survey clearly shows that there is a strong need for a tool that can help bridge the communication gap between hearing and non-hearing individuals. The feedback supports the development of the proposed SignBridge application, which aims to make communication easier, faster, and more inclusive for everyone.


Exploring the Need for an Indian Sign Language (ISL) Conversion Applicati
Published
Questions
Responses 59
Settings
Exploring the Need for an Indian Sign Language (ISL) Conversion Application भारतीय सांकेतिक भाषा (ISL) रूपांतरण एप्लिकेशन की आवश्यकता का अन्वेषण
Target Group: Deaf/Hard of Hearing individuals, ISL users, Parents, Teachers, Caregivers, and General Public
लक्षित समूह: बधिर/कम सुनने वाले व्यक्ति, भारतीय सांकेतिक भाषा (ISL) उपयोगकर्ता, माता-पिता, शिक्षक, देखभाल करने वाले, और सामान्य जनता।
This form is automatically collecting emails from all respondents. Change settings
Age Group: *
आयु वर्ग:
Under 18
18–24
25–34
35–44

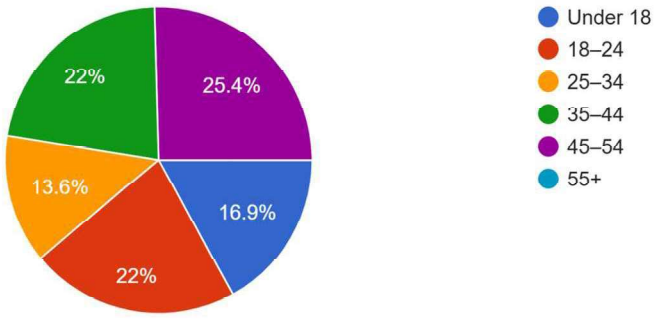

Your Role (select one or more): *
आपकी भूमिका (एक या अधिक चुनें):
Parent/Guardian of a child with hearing/speech impairment सुनने/बोलने में अक्षम बच्चे के माता-पिता/अभिभावक
Teacher/Instructor of deaf or hard-of-hearing students बधिर या कम सुनने वाले छात्रों के शिक्षक/प्रशिक्षक
Caregiver देखभाल करने वाला
Healthcare/Support Staff स्वास्थ्य सेवा/सहायता कर्मचारी
General Public/Other सामान्य जनता/अन्य

Timestamp	Email Address	Age Group: आयु वर्ग:	Your Role (select one or more): आपकी भूमिका (एक या अधिक चुनें):	Do you have a family member, student, or someone close who uses Indian Sign Language (ISL)? क्या आपके परिवार में कोई सदस्य, छात्र या करीबी व्यक्ति है जो भारतीय सांकेतिक भाषा (ISL) का उपयोग करता है?	Where do ISL users face the most communication difficulties? ISL उपयोगकर्ताओं को सबसे अधिक संचार कठिनाइयाँ कहाँ होती हैं?	Do you think an app that can recognize ISL gestures and translate them to text or speech is needed? क्या आपको लगता है कि एक ऐसा ऐप आवश्यक है जो ISL इशारों को पहचानकर उन्हें टेक्स्ट या भाषण में अनुवाद कर सके?	Which features would you like to see in such an app? आप ऐसे ऐप में कौन-कौन सी विशेषताएँ देखना चाहेंगे?	What additional features or improvements would you suggest for such a system? आप ऐसे सिस्टम के लिए कौन-कौन सी अतिरिक्त विशेषताएँ या सुधार सुझाएंगे?
4/25/2025 12:30:39	apekshathku123456@gmail.com	35–44	Teacher/Instructor of deaf or hard-of-hearing students बधिर या कम	Yes हाँ	Public transport सार्वजनिक परिवहन	Yes हाँ	Real-time ISL gesture recognition रीयल-टाइम ISL इशारा पहचान, Custom	सभी को आय एस एल की जानकारी होनी चाहिये
4/25/2025 12:31:04	himalisuroshi09@gmail.com	18–24	Parent/Guardian of a child with hearing/speech impairment	Yes हाँ	Educational institutions शैक्षणिक संस्थान, Hospitals/clinics अस्पताल/क्लिनिक	Yes हाँ	Real-time ISL gesture recognition रीयल-टाइम ISL इशारा पहचान	
4/25/2025 12:52:22	salunked32@gmail.com	45–54	Teacher/Instructor of deaf or hard-of-hearing students बधिर या कम	Yes हाँ	Government offices सरकारी कार्यालय	Yes हाँ	Real-time ISL gesture recognition रीयल-टाइम ISL इशारा पहचान	
4/25/2025 12:52:33	savitakawade1975@gmail.com	45–54	General Public/Other सामान्य जनता/अन्य	Yes हाँ	Educational institutions शैक्षणिक संस्थान, Hospitals/clinics अस्पताल/क्लिनिक	Yes हाँ	Multilingual support (regional languages) बहुभाषी समर्थन (क्षेत्रीय भाषाएँ)	
4/25/2025 12:53:29	bhaskarkumbharde78@gmail.com	45–54	General Public/Other सामान्य जनता/अन्य	Yes हाँ	Educational institutions शैक्षणिक संस्थान, Hospitals/clinics अस्पताल/क्लिनिक	Yes हाँ	Speech-to-sign translation भाषण से संकेत अनुवाद, Multilingual support	
4/25/2025 12:53:41	guraoanusuya@gmail.com	45–54	General Public/Other सामान्य जनता/अन्य	Yes हाँ	Workplaces कार्यस्थल	Yes हाँ	Multilingual support (regional languages) बहुभाषी समर्थन (क्षेत्रीय भाषाएँ)	
4/25/2025 12:55:26	kshirsagardatta2013@gmail.com	35–44	Teacher/Instructor of deaf or hard-of-hearing students बधिर या कम	No नहीं	Educational institutions शैक्षणिक संस्थान, Hospitals/clinics अस्पताल/क्लिनिक,	Yes हाँ	Real-time ISL gesture recognition रीयल-टाइम ISL इशारा पहचान,	जिनको सायन लैंग्वेज पता है उनके लिये ये फायदेमंद है जो लोगो को सायन लैंग्वेज नही आती



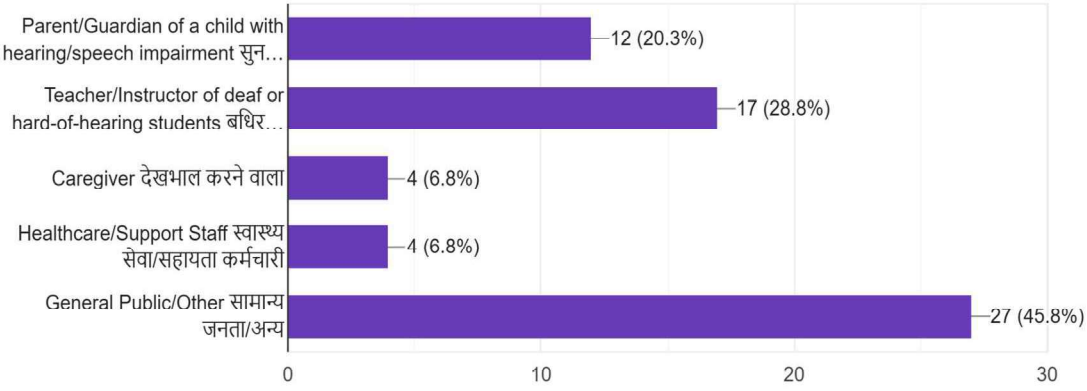
Age Group: आयु वर्ग:

59 responses



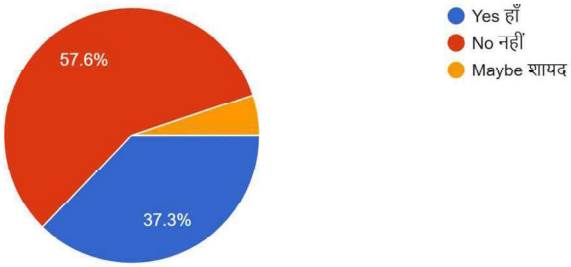
Your Role (select one or more): आपकी भूमिका (एक या अधिक चुनें):

59 responses



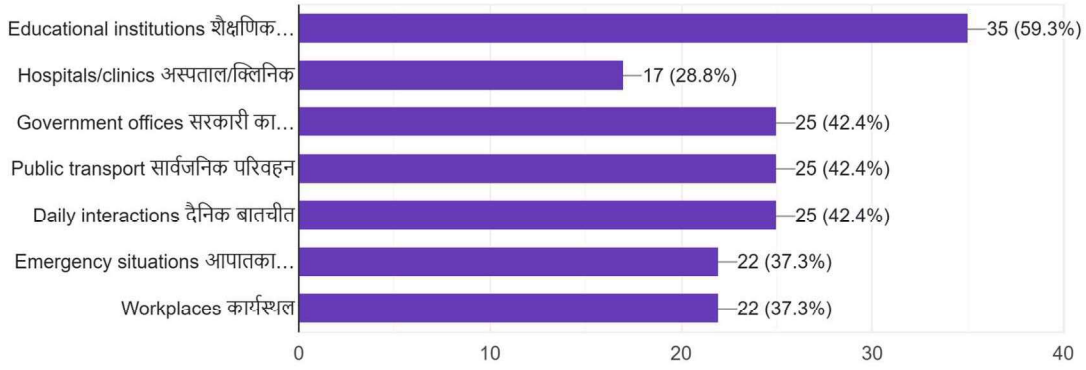
Do you have a family member, student, or someone close who uses Indian Sign Language (ISL)?
क्या आपके परिवार में कोई सदस्य, छात्र या करीबी व्यक्ति है जो भारतीय सांकेतिक भाषा (ISL) का उपयोग करता है?

59 responses



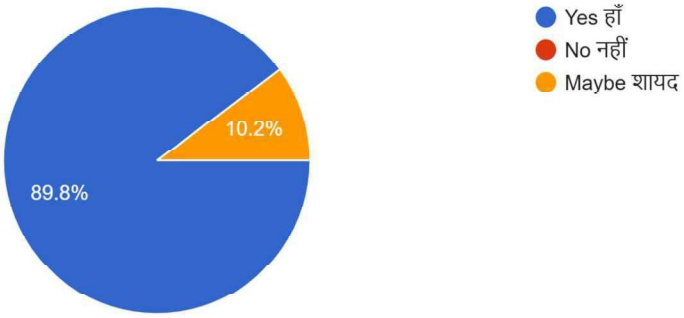
Where do ISL users face the most communication difficulties? ISL उपयोगकर्ताओं को सबसे अधिक संचार कठिनाइयाँ कहाँ होती हैं?

59 responses



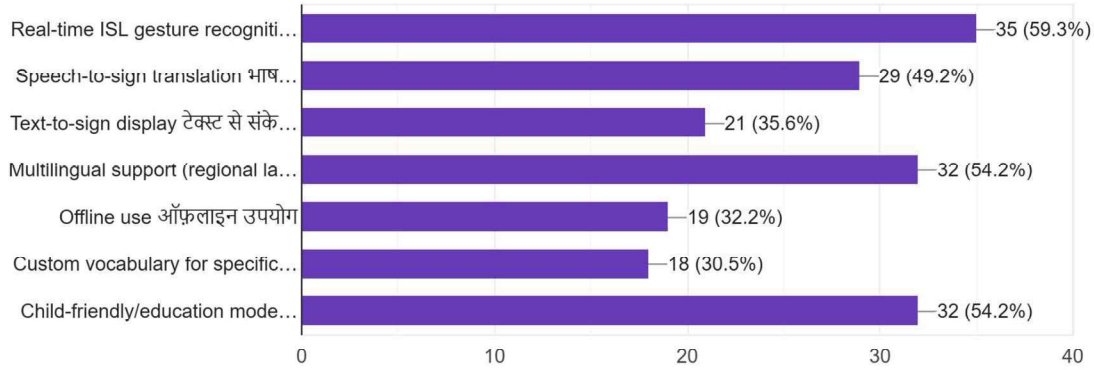
Do you think an app that can recognize ISL gestures and translate them to text or speech is needed? क्या आपको लगता है कि एक ऐसा ऐप आवश्यक है ज... पहचानकर उन्हें टेक्स्ट या भाषण में अनुवाद कर सके?

59 responses



Which features would you like to see in such an app? आप ऐसे ऐप में कौन-कौन सी विशेषताएँ देखना चाहेंगे?

59 responses



SignBridge: A Multimodal Framework for Indian Sign Language Recognition and Translation with Marathi Language Support

ORIGINALITY REPORT

6%	3%	4%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Anant Kumar Jayswal, Aashir Hafeez, Suryansh Singh, Ujjwal Singh, Priyanshu Agarwal. "Chapter 7 Real-Time Sign Language Recognition Using Convolutional Neural Networks", Springer Science and Business Media LLC, 2025 Publication	1%
2	ojs.trp.org.in Internet Source	<1%
3	Submitted to American Public University System Student Paper	<1%
4	Salman Khan, Fahad Shahbaz Khan, Ashish Vaswani, Niki Parmar, Ming-Hsuan Yang, Mubarak Shah. "Guest Editorial Introduction to the Special Section on Transformer Models in Vision", IEEE Transactions on Pattern Analysis and Machine Intelligence, 2023 Publication	<1%
5	ijrpr.com Internet Source	<1%
6	Seema Rawat, Neelu Jyothi Ahuja, Avita Katal, Praveen Kumar, Shabana Urooj. "Data Analytics using Machine Learning Techniques on Cloud Platforms", CRC Press, 2025 Publication	<1%

University of Mumbai

Mahatma Jotirao Phule Bhavan, Vidyanagri, Santacruz (E), Mumbai - 400 098.

RECEIPT NO.: 3589 **DATE :** 22/08/2025

GENERAL FUND - I

Received from TALEKAR KANCHAN the sum of Rupees

Paise Only

by cash being the amount of

PHD TOPIC APPROVAL FORM FEE

TOPIC APPROVAL FEES Rs. **********200.00

Total: Rs. **********200.00

Cash Receiver's Signature **Finance & Accounts Officer**

1. Receipt subject to the realisation of Cheque / Draft etc., it tendered.
2. No. duplicate receipt will be issued.
3. The statement of marks should be collected from Ground Floor, Window No. 2 after 15 working days on production of the receipt and if not collected within 3 months no responsibility lies on the University.